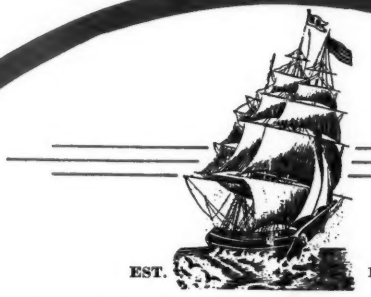
The American Fertilizer

94 APRIL 12, 1941 No. 8



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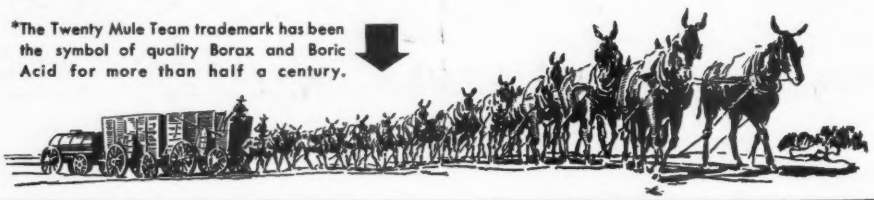

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Vol. 94 APRIL 12, 1941 No. 8

Liebig and the Organic Nutrition of Plants*

By H. R. KRAYBILL

Department of Agricultural Chemistry, Purdue University Agricultural Experiment Station, Lafayette, Indiana

IN considering the importance of Liebig's (1803-1873) contributions on the organic nutrition of plants, it is helpful to recall briefly the status of the sciences of chemistry and physiology at that time. The preceding (eighteenth) century witnessed both the rise and the downfall of the phlogiston theory. During the latter half of that century the work of Margraf, Bergman, Scheele, Black, Priestley, Cavendish and Lavoisier disproved the phlogiston theory and laid the basis for the development of modern chemistry. However, these newer conceptions were accepted only gradually by the scientific world. For, although Priestley discovered oxygen in 1774, he continued to hold to the phlogiston theories almost to the time of his death in 1804.

Ingen-Housz is credited with the discovery, during the eighteenth century, of the role of carbon dioxide in plant economy through the process of photosynthesis. But it was not until 1804 that de Saussure established it on a sound basis by quantitative methods. De Saussure also showed that certain minerals derived from the soil are essential for plant life and that plants obtain an important part of their nitrogen from the soil. From 1802 to 1812 Sir Humphry Davy annually delivered a series of lectures before the Royal Society of London. These lectures were published in book form in 1813. It was a good presentation of the current scientific facts.

But these scientific facts were not generally accepted by the botanists and agriculturalists, especially in continental Europe. The botanists, dominated largely by the systematic viewpoint of Linneaus, failed to recognize the importance of the application of chemistry in physiology. On the other hand, the agriculturalists were greatly influenced by the so-called "humus" theory of Thaer.

In 1809-1810 Thaer published his book entitled "Principles of Rational Agriculture" in which he proposed the "humus" theory of soil fertility. He believed that plants obtained their nourishment from the humus and that it is the material which determines the productivity of the soil. The influence of this theory was so strong during the first half of the nineteenth century that it was generally believed that humus furnished the carbon compounds necessary for the organic nutrition of the plant. Even the noted chemist Berzelius strongly maintained that viewpoint.

Although Liebig's studies in the chemistry of numerous organic constituents of plants contributed much information on the organic nutrition of plants, his chief contribution was his influence in discrediting the humus theory. In 1840 he visited England and made a report to the Royal Society entitled "Chemistry in its Application to Agriculture and Physiology." This report created much discussion. He berated plant physiologists for their lack of chemical knowledge and took them to severe task for ignoring the evidence that plants receive their carbon supply from the carbon dioxide of the air rather than from the humus of the soil. He stated: "All explanations of chemists must remain without fruit and use-

* A paper presented at the "Liebig Symposium," American Chemical Society meeting, Detroit, September 9-13, 1940.

less because, even to the great leaders in physiology, carbonic acid, ammonia, acids and bases are sounds without meaning, words without sense, terms of an unknown language, which awaken no thought and no association.

"The opinion that the substance called *humus* is extracted from the soil by the roots of plants, and that the carbon entering into its composition serves to nourish their tissues without previously assuming another form, is considered by many so firmly established that any evidence in its favor has been deemed unnecessary; the obvious differences in the growth of plants according to the known abundance or scarcity of *humus* in the soil seemed to afford incontestable proof of its correctness.

"Yet, this position, when submitted to a strict examination, is found to be untenable, and it becomes evident from most conclusive proofs, that *humus* in the form in which it exists in the soil, does not yield the smallest nourishment to plants."

Evidence Against The Humus Theory

As evidence against the humus theory, Liebig called attention to the insolubility of humic acid in water. Against the argument of plant physiologists that the humic acid may be absorbed by plants as soluble alkali salts, he showed by calculation that if all of the metallic oxides of the fir tree were absorbed as humic acid salts, it would account for not over 165 lb. of dry wood per Hessian acre. Actually as much as 2,650 lb. of fir wood is produced per acre. Similar calculations were made for wheat, hay and numerous other crops.

He showed that, although a certain amount of carbon is removed each year from the forest or meadow in the form of wood or hay, the soil becomes richer in humus. Against the argument that the carbon removed in leaves, stems, seeds or fruit is replaced by manure applied to the fields and the orchards, he stated: "It cannot be conceived that the laws for the nutrition of plants are changed by culture—that the sources of carbon for fruit or grain, and for grass or trees in meadows and forests, are different."

Liebig recognized the value of manure and humus in agricultural practices but he maintained strongly that they did not serve the plants as a source of carbon compounds. He stated: "The carbon must be derived from other sources; and as the soil does not yield it, it can only be extracted from the atmosphere."

He recognized that in darkness plants take up oxygen and give off carbon dioxide to the surrounding atmosphere. The absorption of oxygen, he believed, was not due to true respiration as in animals, but to a chemical process independent of the living processes, since it was known to occur even in dead plant tissue. The emission of carbon dioxide was attributed to a mechanical process. He stated: "A cotton wick, inclosed in a lamp containing a liquid saturated with carbonic acid, acts exactly in the same manner as a living plant in the night. Water and carbonic acid are sucked up by capillary attraction, and both evaporate from the exterior part of the wick. Most vegetable physiologists have connected the emission of carbonic acid during the night with the absorption of oxygen from the atmosphere, and have considered these actions as a true process of respiration in plants, similar to that of animals, and, like it, having for its result the separation of carbon from some of their constituents. This opinion has a very weak and unstable foundation." His failure to recognize the process of respiration in plants prevented him from appreciating the important role of organic nutrients in plant growth and development.

The Mineral Nutrient Theory

The mineral nutrient theory, to which Liebig made many important contributions, received much attention by agriculturalists and botanists throughout the latter part of the nineteenth century. These studies dealt primarily with a determination of the elements which are necessary for plant growth and development. Investigations of the effect of soil, cultural practices, climate and fertilizer applications on the composition of crops dealt chiefly with their mineral constituents. Little attention was given to their effect on the organic constituents of the plant.

During the latter part of the nineteenth and early part of the twentieth century, Klebs directed attention to the important role that the organic nutrients play in determining the vegetative and reproductive responses of plants. He worked with algae, fungi, and later with higher plants. By controlling the environmental conditions it was possible to cause the plants to remain vegetative, to produce zoospores or to reproduce sexually. The controlling factors were the supply of nutrient salts, especially nitrogenous salts, and the light intensity as it affected the synthesis of organic substances such as carbohydrates.

Fischer advanced the idea that a high ratio of carbohydrates to nitrogen favored flower formation in plants. Remy working with the apple and Petri with the olive concluded that

a proper relation of carbohydrate and nitrogen supply was necessary for fruit bud formation. Kraus and Kraybill studied intensively the relation of carbohydrate and nitrogen supplies to growth and reproduction in the tomato. Subsequently many studies of this relationship have been reported by horticulturalists, agronomists and physiologists. These studies show that with many plants it is possible to recognize a graded series of responses, with reference to carbohydrate and nitrogen supply, under the environmental conditions existing in practical culture of farm crops and orchards. Four types of performance are well recognized. Other environmental factors, such as length of day and temperature, that in themselves affect plant metabolism with certain species of plants, counteract the nutrient conditions in the soil.

Four Types of Growing Conditions

In Group 1 there is an abundant supply of nitrogen but the supply of available carbohydrates or the opportunity for their synthesis is limited. Such plants are weakly vegetative, grow slowly, and tend to die if the carbohydrate supply is restricted. In practice, plants of this type are represented by densely shaded plants or plants that have been subjected to heavy removal of leaves and above-ground portions by insects, pruning, or grazing. These plants are relatively high in moisture and nitrogen, and low in carbohydrate content.

In Group 2 there is available an abundant supply of mineral nutrients, especially nitrogen, and moisture and an available supply of carbohydrates or an abundant opportunity for their synthesis. These plants tend to grow vigorously and many produce flowers but fail to set or mature much fruit. Plants of this type are found on rich soils high in nitrogen and in cases where heavy applications of nitrogenous fertilizers are made. These plants are very succulent and are relatively high in moisture and nitrogen and low in carbohydrates.

In Group 3 there is an opportunity for accumulation of carbohydrates or fats in excess of the amounts used in synthesis of vegetative tissues. In practice this occurs when the nitrogen supply is somewhat limited and there is a good opportunity for synthesis of carbohydrates. Plants in this group are less succulent than those in Group 1. They tend to bloom, set and mature more fruit. These plants are intermediate in moisture, carbohydrate and nitrogen content.

In Group 4 the available supply of nitrogen or other mineral nutrients such as potassium or phosphorus is definitely limited. These plants make very little growth. When nitrogen is the limiting factor, they are pale yellow in color. The stems and leaves are stiff and woody. Considerable flower production may occur, but fruit setting and development are greatly reduced. The plants contain large amounts of carbohydrate reserves, frequently including large amounts of starch. They are usually low in nitrogen content. If phosphorus is the limiting factor, the plants may have a dark green color and contain larger amounts of nitrogen. A relatively large amount of the nitrogen may then be present in a water-soluble form, even though an adequate supply of carbohydrates is available. With the limited phosphorus supply these plants are unable to utilize the nitrogen and carbohydrates in the synthesis of organic compounds necessary for vegetative development.

Other Factors Affecting Growth

During the last two decades horticulturalists, agronomists and physiologists have carried out extensive studies of the carbohydrate-nitrogen relationships in the growth and development of many of our farm crops. These studies have contributed much toward a beter understanding of the principles underlying the responses of plants to the many cultural practices such as fertilizer applications, pruning of fruit trees, pasturing of grasses, cutting of crops for hay, and rate of seeding. A few illustrations of the many available will be discussed briefly.

The ability of plants to absorb and utilize mineral nutrients may be influenced just as greatly by the treatment given to the above-ground portions of the plant as by the soil type and fertilizer applications. This fact is frequently not realized by soil scientists when attention is devoted almost exclusively to the soil. Recent studies have shown that mineral nutrients are absorbed and accumulated by plants only when there is a reserve food supply within the plant to furnish the necessary energy for the process. Thus the ability of the plant to synthesize and accumulate carbohydrates plays an important role in its ability to absorb and utilize mineral nutrients. Factors such as sunshine, moisture, temperature, and leaf area are important in controlling carbohydrate synthesis. Studies of records of sunshine and temperature have been made in connection with fertilizer practices with a number of crops. In the case of pineapples and sugar cane in Hawaii, these studies have resulted in changes of fertilizer practices which have resulted in savings, as

(Continued on page 24)

FERTILIZERS FOR RICE IN TEXAS

Fertilizer experiments with rice on Lake Charles and Crowley clay soils at the Rice Experiment Station, Beaumont, Texas, from 1930 to 1940 show definitely that these soils respond more readily to applications of nitrogen than phosphate fertilizers. Moderate applications of nitrogen in sulphate of ammonia, 100 to 150 pounds per acre, have given more profitable results than lighter or heavier applications. Sulphate of ammonia used at the rate of 150 pounds per acre produced the most profitable yields of rice during the test. The average increase over the unfertilized plats was 406 pounds per acre, equivalent to about $9.75. This was a profit of about $7.50 above cost of fertilizer. Superphosphate alone did not produce any appreciable increase in yield, although a combination of superphosphate and sulphate of ammonia produced larger yields than the latter alone in the last few years.

Although neighboring growers cooperate well with the Experiment Station and show confidence in station results, they, nevertheless, are interested in the success of fertilizer applications made by the farmers themselves under farm conditions. For this reason a number of cooperative experiments with farmers in the area were arranged. These tests revealed that different soils respond differently to fertilizers applied to rice. For the experiments in Liberty and Orange counties applications of superphosphate gave slightly larger yields of rice than applications of nitrogen. On the other hand, in the test near Nome, which is located on Lake Charles and Crowley clay soils that have been grown to rice every second or third year for a long time, nitrogen gave somewhat better results than superphosphate. At Liberty a combination of nitrogen and phosphoric acid produced an increase in yield of rice of 558 pounds per acre, which made a profit of $13.40. In all of these cooperative experiments a combination of sulphate of ammonia and superphosphate gave the largest yields of rice.

Exports and Imports

Larger Exports of Phosphate Rock and Potash

Exports of fertilizers and fertilizer materials from the United States in February totaled 94,316 long tons, valued at $1,289,231. Total tonnage was well above last year, with large increases reported in shipments of phosphate rock and potash. The United Kingdom took most of the phosphate rock, with the remainder going to Japan and South Africa. Japan took two-thirds of the month's exports of potash. Brazil was the largest customer for superphosphate.

January-February exports were nearly double those in the same period last year and were considerably larger than two years ago. Sharp declines in exports of nitrogenates were more than offset by increases in the phosphate and potash groups.

Nitrogenous Material Imports Above Last Year

Reflecting the complete stoppage of potash imports from Europe, total fertilizer imports in February were comparatively low. Totaling 97,677 long tons, with a stated valuation of $2,108,708, they were 34 per cent under last year in volume and 35 per cent less in value. Sodium nitrate and cyanamide were imported in larger quantity than a year ago; other principal changes in the nitrogenous group were sharp declines in ammonium sulphate and ammonium nitrate mixtures.

Exports and Imports of Fertilizers and Fertilizer Materials—Long Tons

EXPORTS	February			January-February		
	1941	1940	1939	1941	1940	1939
Nitrogenous materials	40,254	26,506	54,552	74,586	83,133	118,406
Phosphate rock	46,021	44,943	43,672	86,876	87,516	94,028
Other phosphate materials	8,484	10,180	5,056	14,959	17,324	13,928
Potash salts	1,436	65,486	6,795	4,201	107,284	26,981
Other fertilizers	1,482	860	772	2,635	1,100	3,422
Grand Total	94,316	53,398	85,095	203,970	110,000	170,512

IMPORTS	February			January-February		
	1941	1940	1939	1941	1940	1939
Sodium nitrate	11,031	28,902	15,645	20,367	56,066	26,962
Other nitrogenous materials	70,812	16,708	62,068	155,626	37,298	130,865
Phosphate materials	5,521	3,009	4,664	8,405	9,518	6,787
Potash salts	6,450	475	2,132	18,269	1,199	4,276
Other fertilizers	502	4,304	586	1,303	5,919	1,622
Grand Total	97,677	147,975	110,847	183,257	296,357	256,765

Potash in 1940

THE domestic potash industry, developed since World War I, as a result of the acute shortage experienced at that time when the flow of potash from European sources was interrupted, functioned smoothly during 1940 and supplied all the potash needed to supplement such imports as continued to arrive and prevent any scarcity of salts for fertilizer and other uses, according to the Bureau of Mines, United States Department of the Interior. Although little if any importations from Europe may be expected in 1941, the industry is capable of meeting all domestic requirements, thus definitely removing potash from the category of strategic and critical materials, with which Government stock piling is concerned.

Production in the United States in 1940 of 658,249 short tons of processed or refined potash salts, containing approximately 379,679 tons of K_2O is shown by reports of producers to the Bureau of Mines. This represents a gain over 1939 of 20 per cent in material produced and about 22 per cent in K_2O. Sales of potash salts by the producers amounted to 677,892 tons, an increase of 7 per cent over 1939, and contained about 393,058 tons of K_2O. The average K_2O content of the salts sold was slightly higher in 1940 (57.98 per cent) than in 1939 (57.77 per cent) with the increase a little more than 7 per cent. The value of the sales amounted to $12,562,050 or about 4 per cent more than in 1939. Processed stocks held by producers amounted to about 35,000 tons, containing 16,000 tons of K_2O; stocks of crude mined material held were 37,000 tons, containing 8,000 tons of K_2O.

The principal processed or refined salts produced in 1940 were manure salts, muriate, and sulphate. There was produced commercially in 1940, for the first time in the United States from domestic ores, sulphate of potash-magnesia, which has been regarded as indispensable to the fertilizer industry of this country and hitherto supplied by importations not now available. The production of sulphate of potash has increased noticeably in the last two years as has the production of high-grade muriate for the manufacture of chemicals. A small quantity of mixed salts is also included in the total figures.

Operations near Carlsbad, New Mexico, which now furnish the largest part of the potash materials, are carried on by the Potash Co. of America, United States Potash Co., Inc., and by the Union Potash and Chemical Co., which operated commercially for the first time in 1940. The latter company produces langbeinite from which the sulphate of potash-magnesia is made. Sylvinite is also produced at this mine. The total crude ore mined in the Carlsbad region in 1940 was over 1,200,000 tons, and the refined and processed salts produced amounted to over 440,000 tons.

(Continued on page 22)

Salient Statistics of the Potash Industry in the United States, 1939-1940

		1940	1939
Production:			
Potassium salts (merchantable)	short tons	658,249	[1]546,757
Approximate equivalent, K_2O	short tons	379,679	[1]312,201
Sales by producers:			
Potassium salts	short tons	677,892	634,014
Approximate equivalent, K_2O	short tons	393,058	366,287
Value at plant		$12,562,050	$12,028,195
Average per ton		$18.53	$18.97
Imports:			
Fertilizer materials	short tons	274,473	237,236
Approximate equivalent, K_2O	short tons	115,241	94,297
Value		$5,148,852	$5,752,225
Other	short tons	14,564	18,576
Approximate equivalent, K_2O	short tons	3,449	5,832
Value		$2,411,919	$2,406,109
Exports:			
Fertilizer materials	short tons	93,060	136,750
Approximate equivalent, K_2O	short tons	55,800	82,000
Value		$3,141,170	$4,446,853
Other	short tons	14,180	3,579
Approximate equivalent, K_2O	short tons	7,000	1,800
Value		$3,096,909	$807,987

[1] Revised.

Justus Liebig, the Man and His Contributions to Human Progress*

By C. A. BROWNE

(Continued from the March 29th issue)

A KNOWLEDGE of Liebig's personality and of certain facts of his career is necessary for anyone who desires to form a correct evaluation of his book on "Organic Chemistry in its Application to Agriculture and Physiology." This work was the result of a request made to Liebig at the 1837 meeting of the British Association for the Advancement of Science in Liverpool that he prepare a report on the present state of organic chemistry and organic analysis.

Liebig's great prominence as an organic chemist did not qualify him, however, in 1840 to become an authority on agricultural chemistry. While his laboratory researches gave him a wide acquaintance with plant and animal substances, he lacked that practical experience with farm operations which was the strong endowment of his French contemporary Boussingault who, for the experiments conducted on his estate at Bechelbronn in Alsace, deserves the credit of first taking chemistry from the laboratory to the field and stable. As has been truly stated by Sir E. J. Russell, "to Boussingault belongs the honor of having introduced the method by which the new agricultural science was to be developed."

The assertion of Liebig in the preface of his book that since the time of Davy no chemist had "occupied himself in studying the applications of chemical principles to the growth of vegetables" is abundantly contradicted by the names of the chemists to whom he refers. Having had no practical experience in agriculture, all that Liebig could do in the first edition of his book was to make a critical review of pre-existing knowledge and to select therefrom those principles which appeared to his brilliant chemical genius as the most scientific and plausible. His book contains over 200 references to the work of a hundred different authors. Chief among these writers is Theodore de Saussure whom Liebig quotes no less than 24 times. Berzelius, Boussingault, Davy, Gay-Lussac, Sprengel and Schübler are among other eminent chemists whose works were consulted by Liebig. In asserting that since the publication of Davy's "Elements of Agricultural Chemistry" in 1813 no chemist had occupied himself with the subject until he again took it up, Liebig spoke as a propagandist. His tendency to exaggerate, or to understate, must constantly be borne in mind.

In the numerous works on the chemistry of soils and crops which preceded the publication of Liebig's book, many of the fundamental principles of agricultural chemistry had been elucidated, but simultaneously with this development many faulty hypotheses had been announced. The publications relating to agricultural chemistry were a confused mixture of truth and error, and until Liebig appeared no one had attempted to sift this heterogeneous collection of data and to compile therefrom a definite chemical code of agriculture.

The attempt to codify a science in the period of its early development may have a double influence. It may be beneficial, on the one hand, in helping to divest the science of false ideas and unessential trappings; on the other hand it may be detrimental in setting up faulty generalizations as fixed principles of guidance.

Errors in Liebig's Theories

The general influence of Liebig and his school upon agriculture was so preponderatingly beneficial that a discussion of the detrimental effects of some of his teachings need not long detain us. The pages of the first edition of his agricultural chemistry are sprinkled with errors but we will only cite one of them for the purpose of showing how Liebig used his mistakes as stepping stones to the discovery of truth. The error in question is expressed as follows in the English translation of the first 1840 edition of Liebig's book (pages 152-3):

"One hundred parts of the stalks of wheat yield 15.5 parts of ashes (H. Davy); the same quantity of the dry stalks of barley, 8.54 parts (Schrader); and one hundred parts of the stalks of oats, only 4.42; the ashes of all of these are of the same composition. We have in these facts a clear proof of what plants require for their growth. Upon the same field, which will yield only one harvest of wheat, two crops of barley and three of oats may be raised."

Every assertion in this passage (expressed so dogmatically and without qualification) is

* A paper presented at the "Liebig Symposium" American Chemical Society meeting, Detroit, September 9-13, 1940.

erroneous. Liebig's conclusions were not only wrong in principle, but they were further vitiated, as in so many other parts of his book, by the acceptance of unreliable analytical data. When this passage was written, he had not begun to make the analyses of plant ashes that were pursued so energetically in his laboratory two years later. Criticisms obliged Liebig to rectify this mistake and to submit his unconfirmed statements to rigid analytical verification. He recognized somewhat tardily that published analyses were faulty and that the development of improved analytical methods must be made the basis of all future progress in agricultural chemistry. To his students, Fresenius, Will and others was assigned the task of developing such methods, and thus were initiated those investigations which bore such splendid results in the publication of the classic treatise of Fresenius on qualitative and quantitative analysis. The first and, in many respects, the best fruits of Liebig's new school of agricultural chemistry was the great reform that was accomplished in analytical methods. It was only after this achievement that dependable information on the composition of soils and of the mineral constituents of plants began to be secured.

Liebig's Book Gets Mixed Reception

The comments which followed the appearance of Liebig's book created a furore of mingled praise and criticism. Liebig himself was conscious of his book's imperfections and explained that what he tried to do was not to write a systematic handbook of agricultural chemistry, but to point out a few of the relationships of chemical laws to established farm usages and to show how theory and practice coincide. He stated that his book, if interpreted as a system, is a disorderly work and one that is filled with contradictions.

Liebig laid great stress upon the year 1840, in which his book appeared, as the dividing line or turning point between the old agricultural chemistry and the new. By quoting isolated passages from the publications of Berzelius, Thaer, Sprengel and other previous writers, he attempted to prove that before the appearance of his book the most distinguished scientists of Europe believed that the fertilizing action of manures was due exclusively to their content of humus. Liebig, however, spoke here as a propagandist, for he completely ignored the fact that long before the appearance of his book Carl Sprengel, abandoning earlier vitalistic conceptions, had announced opinions with regard to humus and mineral fertilizers that were almost identical with those which he himself afterwards proclaimed. Indeed, when Liebig stated that the alkali and alkaline earth bases were mutually replaceable in their action on plants, it was Sprengel who, on the basis of his more extensive practical knowledge, pointed out that was not the case. Historians of chemistry and biographers of Liebig have unfortunately neglected to acquaint themselves sufficiently with the literature of agricultural chemistry between 1820 and 1840. Had this been done, they might have given a far more accurate picture of Liebig's relationship to the events of this period than has heretofore been published.

Effect on the United States

The effects of Liebig's book in the United States were most wide and pronounced. This is shown not only by the attention which the work received among chemists, but by the extracts, notices and comments that were published by American agricultural journals in all parts of the country. The controversial character of these discussions, in which some of Liebig's American pupils participated, served to stimulate a wide interest in agricultural chemistry.

A reference to the agricultural periodicals of this period will indicate how the farming public of America, after the publication of Liebig's book, was rapidly becoming chemically minded. It is shown, for example, by an editorial of the "Southern Cultivator" for April, 1845, in which the demand was made that the system of education in the State University of Georgia shall include a Professorship of Agricultural Chemistry and Geology.

The tendency in this direction, however, had been gathering force long before the publication of Liebig's book, as the favorable references by our agricultural periodicals to the agricultural chemistries of Davy, Chaptal, and other predecessors of Liebig indicate. It was Liebig's achievement to give the final decisive thrust at the right psychological moment to a movement that had been slowly acquiring momentum since the time of Lavoisier.

His extensive writings and those of the loyal graduates of his school gave his doctrines a vogue that no other chemist has enjoyed. Evidences of this publicity in the United States are found, for example, in the printing of Liebig's article "On Artificial Manures" in the U. S. Patent Office Report on Agriculture for 1845, in which Liebig made the following famous prediction:

(Continued on page 22)

THE AMERICAN FERTILIZER
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A MAGAZINE INTERNATIONAL IN SCOPE AND CIRCULATION DEVOTED EXCLUSIVELY TO THE COMMERCIAL FERTILIZER INDUSTRY AND ITS ALLIED INDUSTRIES

PIONEER JOURNAL OF THE FERTILIZER INDUSTRY

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Expenditures for Plant and Equipment for the Fertilizer Industry

Establishments which accounted for 74.3 per cent of the value of products manufactured in the fertilizers industry reported total capital expenditures for plant and equipment for 1939 amounting to $2,354,976, according to preliminary figures compiled from the returns of the 1939 Census of Manufacturers, taken in 1940, and released by Acting Director Vergil D. Reed, Bureau of the Census, Department of Commerce. The remaining establishments, which accounted for 25.7 per cent of the total value of products of this industry, did not report any expenditures for plant and equipment during 1939.

The Bureau of the Census obtained for the first time information on the expenditures for plant and equipment by manufacturing establishments. Such establishments were requested to report charges to capital account for new depreciable assets at cost value.

The major portion of these expenditures represented purchases of new machinery valued at $1,457,258, or 61.9 per cent of the total. The cost of new construction was $793,052, or 33.7 per cent of the total, and of plant and equipment acquired in a "used" condition and expenditures for land, $86,506, or 3.7 per cent of the total.

The expenditures for plant and equipment shown in this table include only expenditures reported by establishments engaged in active production during the year 1939.

Summary statistics for 1939 for the industry are shown in the following table:

	Fertilizer Industry
Total number of establishments	764
Number of establishments reporting capital expenditures for plant and equipment	746
Total value of products	$185,684,328
Value of products of establishments reporting expenditures for plant and equipment	137,951,023
Total expenditures for plant and equipment	2,354,976
Expenditures for new construction or major alterations of buildings and other fixed plant and structures	793,052
Expenditures for new machinery and operating equipment	1,457,258
Expenditures for plant and equipment acquired in a "used" condition from other owners and expenditures for land	86,506
Expenditures, unclassified	18,160

Obituary

SYDNEY O. CHASE

A career of over fifty-years in the fertilizer industry was ended by the death on March 31st of Sydney O. Chase, president of Chase & Company, fertilizer manufacturers of Sanford, Florida.

Born in Philadelphia, Mr. Chase moved to Florida when only 18 years of age and in 1884 started the firm of Chase & Company, serving as president until his death last month.

DR. EUGENE DAVENPORT

Dr. Eugene Davenport, dean emeritus of the College of Agriculture, University of Illinois, died at his home in Woodland, Mich., March 31st, at the age of 84. He was dean of the College of Agriculture in Illinois from 1895 until his retirement. Dean Davenport was graduated from Michigan State College in 1878 and entered the field of advanced agricultural work and education at once. He taught at Michigan State and the College of Agronomy in Sao Paulo, Brazil, before going to the University of Illinois in 1895.

CHANGES IN N. C. FERTILIZER LAW PROPOSED

House Bill 495, introduced at the present session of the North Carolina Legislature, would amend the present Fertilizer Control Law with the following principal changes:

"Total available nitrogen" may be guaranteed but shall be interpreted to mean "total nitrogen." "Water insoluble nitrogen" shall be guaranteed in terms of the percentage of "total nitrogen." In tobacco goods nitrate nitrogen may be guaranteed in terms of the percentage of total nitrogen; calcium oxide, magnesium oxide, and sulphur may be guaranteed in all fertilizers in those terms, but sulphur must be guaranteed as to both maximum and minimum content in tobacco goods. A minimum content of 16 per cent of total plant food must be guaranteed except that the grade 3-8-3 may still be sold. Shipments of fertilizer and fertilizer materials to manufacturers who have registered their grades are exempted from the provisions of the Act. Many changes are made in the specific tolerances and penalties for underruns.

FEBRUARY SULPHATE OF AMMONIA FIGURES

That the production of by-product sulphate of ammonia is now pretty well stabilized at about 2,000 tons per day is indicated by figures for February issued by the U. S. Bureau of Mines. The output for that month was 58,360 tons, a decrease of 9.8 per cent from January figures of 64,670 tons. On a per-day basis, each month shows a daily output of 2,084 tons. February, 1940, showed a production of 53,475 tons. For the first two months of the year, the production was 123,030 tons for 1941 and 113,868 tons for 1940.

By-product ammonia liquor during February showed 2,341 tons (NH_3 content), compared with 2,664 tons in January and 2,267 tons in February, 1940. For the January-February period the output was 5,005 tons in 1941 and 4 671 tons in 1940.

SALES IN OHIO AND ILLINOIS REACH RECORD FIGURES IN 1940

Total sales in Ohio in 1940 amounted to 363,320 tons, compared with 345,585 tons in 1939 and 362,206 tons in 1937, the previous peak. The 1940 figure is also incomplete, as a few companies did not report. There has been a strong upward trend in the plant food ratio of fertilizers used in Ohio, particularly in potash. Although reported tonnage was only 0.3 per cent higher in 1940 than in 1937, the amount of plant food was 6.7 per cent larger.

Illinois fertilizer sales in 1940 were the largest on record, amounting to 49,753 tons of mixed goods and materials, excluding 47,823 tons of rock phosphate. The leading grade continued to be 2-12-6, accounting for 30 per cent of all mixed goods. The next four grades, in the order named, were 0-12-12, 3-12-12, 2-8-16, and 0-8-4. In 1936 only 70 per cent of the mixed goods sold in the State contained 20 per cent or more plant food; in 1940 the ratio was 91 per cent.

CHANGE IN FERTILIZER LAW

A change in the New York fertilizer law would require statement of potential acidity or basicity of mixed fertilizers, as well as content of minor elements if latter are claimed to be present. The bill has passed the Legislature and awaits the Governor's signature.

March Tag Sales

Fertilizer sales in March were apparently smaller than in the corresponding month of recent years. Tax tag sales during the month in 17 states amounted to 1,487,101 tons, 9 per cent below last year and 7 per cent below 1939.

Declines from last year in 11 of the 12 southern states much more than offset an increase in the midwest. Georgia was the only state in the south to report an increase over last year, although the decline in Florida was negligible.

The decline in March in sales in the south followed increases in January and February. For the first three months combined there was a small increase reported over the same period of the last two years. In eight of the 12 states first-quarter gains were recorded.

Sales last month in the midwest were 18 per cent larger than a year ago. Increases took place in Indiana and Illinois, while Missouri sales were the same in the two periods and Kentucky and Kansas reported declines. All of the five states reported first-quarter gains, with the increase for the region as a whole amounting to 24 per cent.

FARM INCOME INCREASING

Farm income this year is likely to reach $10,000,000,000 for the first time since 1929, according to the U. S. Department of Agriculture. Farm income last year was $9,120,000,000. Prices of all farm products combined are now at the highest levels reached in the last four years.

FERTILIZER TAX TAG SALES

State	March 1941 Per Cent of 1940	March 1941 Tons	March 1940 Tons	March 1939 Tons	January-March 1941 Per Cent of 1940	January-March 1941 Tons	January-March 1940 Tons	January-March 1939 Tons
Virginia	93	74,304	79,549	87,674	102	171,473	167,783	179,193
N. Carolina	98	310,558	316,098	358,252	101	564,688	558,312	634,533
S. Carolina	89	265,216	298,265	266,468	98	435,254	444,380	411,679
Georgia	107	343,482	319,616	322,062	107	513,384	478,883	454,785
Florida	100	53,517	53,656	45,032	116	203,905	176,007	167,989
Alabama	74	146,950	199,150	199,700	87	271,850	312,950	301,600
Mississippi	65	70,313	108,675	73,825	104	203,252	196,013	139,600
Tennessee	44	10,410	23,456	24,250	101	40,018	39,682	47,461
Arkansas	72	25,800	36,000	24,300	110	72,800	66,200	50,900
Louisiana	65	37,830	57,825	45,000	97	98,930	102,311	93,050
Texas	62	26,817	43,455	29,389	91	69,797	77,016	59,034
Oklahoma	91	2,110	2,320	2,089	151	7,796	5,173	6,018
Total South	89	1,367,307	1,538,065	1,478,041	101	2,653,147	2,624,710	2,545,842
Indiana	120	65,079	54,225	58,482	120	135,687	113,019	94,295
Illinois	236	16,881	7,164	8,832	168	21,029	12,507	16,026
Kentucky	89	20,348	22,786	21,585	114	45,749	40,111	41,008
Missouri	...	16,670	16,670	13,655	128	30,483	23,888	18,765
Kansas	89	816	918	610	213	5,033	2,368	1,315
Total Midwest	118	119,794	101,763	103,164	124	237,981	191,893	171,409
Grand Total	91	1,487,101	1,639,828	1,581,205	103	2,891,128	2,816,603	2,717,251

BRADLEY & BAKER

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NEW YORK

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Jacksonville, Fla.

FERTILIZER MATERIALS MARKET

NEW YORK

Some Improvement in Materials Market with Spring Season under Way. Export Licenses Hard to Obtain for Sulphate of Ammonia. Fish Meal Prices at High Levels.

Exclusive Correspondence to "The American Fertilizer."

NEW YORK, April 8, 1941.

With the movement of mixed goods in fair volume throughout the country, there has been some improvement in the raw materials markets. However, the labor situation in most of the fertilizer plants is causing some concern, especially in plants situated close to manufacturing centers, as the better help is being absorbed by factories working on defense orders.

At the moment export licenses for the exportation of sulphate of ammonia seem to be very difficult to obtain and naturally with lack of export orders, a more normal condition prevails as far as domestic business is concerned.

Nitrate of Soda

Along with the movement of mixed goods, nitrate of soda is now moving in fair volume, with no change in price from previously advised price of $27.00 in bulk.

Superphosphate

Price is steady with no unusual activity.

Potash

Contract movements continue with some improvement for spot material.

Nitrogenous

With the booking of fair quantities of this material during the last week, certain sellers have now increased their price ideas to some extent.

Bone Meal

This material is very scarce with offerings few and far between, based on prevailing freight rate. South American raw bone would figure in the neighborhood of $36.00, provided freight space could be obtained.

Dried Blood

There has been a fair amount of interest, with trades at $3.00 ($3.64½ per unit N). There is further buying interest in the market at this figure but temporarily there are no offerings. South American is quoted at $2.85 to $2.90 ($3.46½ to $3.52½ per unit N), subject to freight and, where spot stocks are available, quotations are on the basis of $3.00 to $3.10 ($3.64½ to $3.70 per unit N), at the ports.

Tankage

This market is quoted at $3.00 ($3.64½ per unit N) and 10 cents for unground 9/10 per cent material.

Fish Scrap

Trading has been done at $4.25 ($5.16½ per unit N) and 10 cents but producers are reluctant to accept further bookings at this level. However, buyers do not appear to be anxious and show no disposition to increase their bids.

ATLANTA

Shipping Season in Full Swing Throughout the South. Not Much Business in Organics as Prices Stiffen.

Exclusive Correspondence to "The American Fertilizer."

ATLANTA, April 8, 1941.

The fertilizer shipping season is on in full swing throughout most of the south. Reports from the extreme southern part of the belt indicate that the movement is beginning to slacken off but for the most part, shipments are going full blast.

There has been some little activity in organic ammoniates recently but no great volume of business has been done as buyers showed no interest when prices began to stiffen.

Acid fish for fertilizer will apparently be scarce for the coming season. Some business has been done coastwise for summer delivery as made.

A Complete Service

THE strategic factory locations of the American Agricultural Chemical Company, as shown on the accompanying map, assure prompt, dependable service for the complete line of products listed below.

We manufacture all grades of Commercial Fertilizers, Superphosphate, Agrinite Tankage, Bone Black, Bone Black Pigments (Cosmic Black), Dicalcium Phosphate, Monocalcium Phosphate, Gelatin, Glue, Ground Limestone, Crushed Stone, Agricultural Insecticides (including Pyrox, Arsenate of Lead, Calcium Arsenate, etc.), Trisodium and Disodium Phosphate, Phosphorus, Phosphoric Acid, Sulphuric Acid, Salt Cake; and we are importers and/or dealers in Nitrate of Soda, Cyanamid, Potash Salts, Sulphate of Ammonia, Raw Bone Meal, Steamed Bone Meal, Sheep and Goat Manure, Fish, Blood and Tin-Tetrachloride. We mine and sell all grades of Florida Pebble Phosphate Rock.

FACTORIES

Alexandria, Va.	Detroit, Mich.	Pierce, Fla.
Baltimore, Md.	East Point, Ga.	Port Hope, Ont., Can.
Buffalo, N. Y.	East St. Louis, Ill.	Presque Isle, Me.
Carteret, N. J.	Greensboro, N. C.	Savannah, Ga.
Cayce, S. C.	Henderson, N. C.	Searsport, Maine
Chambly Canton, Quebec, Can.	Montgomery, Ala.	South Amboy, N. J.
	Norfolk, Va.	Spartanburg, S. C.
Charleston, S. C.	No. Weymouth, Mass.	West Haven, Conn.
Cincinnati, Ohio	Pensacola, Fla.	Wilmington, N. C.
Cleveland, Ohio		Havana, Cuba

The AMERICAN AGRICULTURAL CHEMICAL Co.

50 Church Street, New York City

SALES OFFICES

Alexandria, Va.	Columbia, S. C.	Laurel, Miss.	Pierce, Fla.
Baltimore, Md.	Detroit, Mich.	Montgomery, Ala.	Port Hope, Ont.
Buffalo, N. Y.	East Point, Ga.	Montreal, Quebec, Can.	Savannah, Ga.
Carteret, N. J.	East St. Louis, Ill.	New York, N. Y.	Spartanburg, S. C.
Charleston, S. C.	Greensboro, N. C.	Norfolk, Va.	St. Paul, Minnesota
Cincinnati, Ohio	Henderson, N. C.	No. Weymouth, Mass.	Wilmington, N. C.
Cleveland, Ohio	Houlton, Me.	Pensacola, Fla.	Havana, Cuba

Vegetable meals are somewhat firmer but activity at current levels is lacking.

The quoted markets are as follows:

South American Blood.—$3.00 ($3.64½ per unit N), c.i.f.

Tankage.—$3.15 ($3.83 per unit N) and 10 cents, c.i.f.

Domestic Nitrogenous Tankage.—$1.75 ($2.12½ per unit N), f.o.b. western producing points.

Menhaden Acidulated Scrap.—$3.00 ($3.64½ per unit N) and 50 cents per unit A.P.A., f.o.b. southern factories.

Sulphate of Ammonia.—Unchanged with quite a little resale material becoming available.

Nitrate of Soda.—Demand active. No change in price.

BALTIMORE

Spring Season Started but Demand for Fill-in Materials Not Yet Developed. Burlap Market Conditions Causes Sharp Increase in Bag Prices.

Exclusive Correspondence to "The American Fertilizer."

BALTIMORE, April 8, 1941.

The spring fertilizer season, with more favorable weather conditions during the past week, has gotten under way, but shipments have not yet been of sufficient volume to create any shortage or demand for replenishment of raw materials. The market in the meantime remains firm and materially unchanged.

Ammoniates.—The market on tankage for feeding purposes is again ruling somewhat stronger, being around $3.25 per unit of nitrogen and 10 cents per unit of B.P.L., f.o.b. basis Baltimore. South American ground dried blood has also been marked up to $3.35 per unit of nitrogen, but with only a light demand.

Nitrogenous Material.—This product continues to rule easy with demand practically nil. The nominal market is unchanged at $2.55 to $2.65 per unit of nitrogen, f.o.b. Baltimore.

Sulphate of Ammonia.—There has been practically no demand for re-sale material for domestic consumption, as practically all the manufacturers have arranged their manufacturing program to conform with their contractual requirements, and unless there should be a last minute extra heavy demand for complete fertilizer there will probably be little call for re-sale sulphate. There are practically no offerings on the market for export, and will not be until after the spring shipping season is over.

Nitrate of Soda.—The demand is improving as the season advances, and the market is unchanged. This material is still quoted at $29.40 per ton of 2,000 lb., in 100-lb. bags, with usual differentials for 200-lb. bags and in bulk, f.o.b. port warehouses.

Fish Scrap.—It is reported that initial sales for unground menhaden fish scrap were booked at $4.15 per unit of ammonia ($5.04½ per unit N) and 10 cents per unit of B.P.L., f.o.b. fish factories. for shipment "if and when made."

Superphosphate.—There has been no change in the market on this material which is still ruling firm at $8.00 per ton of 2,000 lb., basis 16 per cent for run-of-pile, and $8.50 per ton of 2,000 lb. for flat 16 per cent grade, no charge for excess, both in bulk, f.o.b. producers' works, Baltimore.

Bone Meal.—All manufacturers seem to be well covered for their current requirements of both raw and steamed bone meal, and the market is, therefore, strictly nominal at $32.00 to $34.00 for 3 and 50 per cent domestic steamed bone meal, and $31.00 to $32.00 for 4½ and 47 per cent South American raw bone meal, f.o.b. sellers' works, Baltimore.

Potash.—There has been no activity or demand for re-sale lots, and it now looks as

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Valuable not only as a source of nitrogen, but also to help maintain the supply of other plant food elements *naturally* blended with it.

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MONTGOMERY, ALA. COLUMBIA, S. C.

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though domestic manufacturers will be able to supply buyers' legitimate current requirements.

Bags.—The market on burlap advanced considerable during the past two weeks, particularly for early delivery, in which position the price is around $181.50 per thousand for plain, new, 10-oz. basis 40 cut 54 in., representing an advance of about $13.50 per thousand. Buying interest is at a minimum. The market for future delivery has also advanced, although there is a difference of over $30.00 per thousand between the market for spot and distant future delivery. The advances during the past month have been heavy, so much so, that there is practically no buying interest being shown, and if the present quotations hold many manufacturers will doubtless displace burlap with either paper, cotton or second-hand bags.

CHARLESTON

Mixed Fertilizer Shipments Quite Heavy. Nitrate of Soda Shipments Slowing Up. Freight Space Scarce for Imported Materials.

Exclusive Correspondence to "The American Fertilizer."

CHARLESTON, April 8, 1941.

The movement of mixed fertilizers is quite heavy just now and the manufacturers are hoping that this will continue for two or three weeks more. The movement of nitrate of soda has slowed up quite considerably. Sulphate of ammonia and potash continue scarce.

According to crop reporting services, cotton planting and germinating has been retarded from two to four weeks by cold, wet soil conditions.

Nitrogenous.—Domestic can be obtained around $2.30 ($2.79½ per unit N) to $2.35 ($2.85½ per unit N) at southeastern ports.

Blood.—Around $3.25 ($3.95 er unit N), bulk, Chicago; $2.85 ($3.46½ per unit N), bagged, c.i.f. Atlantic port, but freight space except to ports Norfolk north continues extremely scarce.

Fish Meal.—No spot material being offered.

Tankage.—Fertilizer grade around $3.00 ($3.64½ per unit N) and 10 cents, f.o.b. Chicago.

Cottonseed Meal.—Around $30.00 for 8 per cent at Atlanta and $26.00 to $26.50 for 8 per cent at Memphis. $27.00 at Augusta for 7 per cent.

USE PLENTY OF SUNSHINE STATE POTASH

● Balanced fertilizers are economical fertilizers. In the case of tobacco, for instance, results definitely prove that considerably more potash than has been applied in the past, can profitably be used to further increase acre values. Potash has a greater influence on quality than any other element in tobacco fertilizer and pays highest dividends to the tobacco grower. Adequate amounts of potash produce a smooth, even leaf of good burning quality which commands a relatively high market value.

Progressive fertilizer producers know it's good business to provide growers of tobacco and all major crops with complete fertilizers containing plenty of potash, compounded to fit the recommendations of local agricultural authorities. They also know that Sunshine State Potash can be relied upon for consistently uniform analysis and careful sizing which makes handling and blending easy.

HIGRADE MURIATE OF POTASH
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Also 50% K_2O Grade
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UNITED STATES POTASH COMPANY, INC., 30 ROCKEFELLER PLAZA, NEW YORK, N. Y.

CHICAGO

Market for Future Organics More Active. Prices Comparatively Low. Feed Market Firm and Well Sold Up.

Exclusive Correspondence to "The American Fertilizer."

CHICAGO, April 7, 1941.

Some interest has been displayed in future organics and a few trades are reported at prices comparatively low, though slightly higher than ruling last year for similar deliveries. There has also been a slight call for prompt shipments to southern points but not to such extent as to affect the normal market.

Stabilizing hog and egg prices have further increased the feed demand and the materials market is very firm and well sold up.

Nominal prices are as follows: High grade ground fertilizer tankage, $2.20 to $2.25 ($2.67½ to $2.73½ per unit N) and 10 cents; standard grades crushed feeding tankage, $3.50 to $3.60 ($4.25½ to $4.37½ per unit N) and 10 cents; blood, $3.30 to $3.40 ($4.01 to $4.13½ per unit N); dry rendered tankage, 67 to 72 cents per unit protein, Chicago basis.

TENNESSEE PHOSPHATE

Shipments of Phosphate Rock and Mixed Fertilizers Continue in Volume.

Exclusive Correspondence to "The American Fertilizer."

COLUMBIA, TENN., April 7, 1941.

March 1941 witnessed the largest shipments of ground rock to farmers from Tennessee of any March in over forty years and April is on the same track so far, notwithstanding the uncertainties and increases of freight rates on rock phosphate. A good spring season for regular commercial fertilizer is also in evidence and all signs point to the increased food production for which U. S. farmers will be called on.

An article in the March issue of the IAA Record gives the results of a demonstration in Peoria County, Illinois, to compare the values of superphosphate, fused phosphate rock, and finely ground phosphate rock on a field of uniform soil that had been adequately limed in 1936 and planted to alfalfa in 1937. One plot had no treatment, one had 250 lb. per acre of 20 per cent superphosphate, one had 250 lb. per acre of fused phosphate rock, and the final plot had 1,000 lb. of 33 per cent finely ground phosphate rock. The 1938 yields showed a net profit of $9.36 per acre for superphosphate, $20.64 for the fused rock and $18.40 for the finely ground rock. For three years, the profits were $19.44 for the superphosphate-treated plot, $30.11 for the fused rock, and $40.96 for the ground rock. During the three years, the crop used up 96 per cent of the phosphoric acid from the superphosphate, 33 per cent from the fused rock and only 13 per cent from the ground rock, which will continue to show profits for another seven years.

HOFFMAN ELECTED LINK-BELT VICE-PRESIDENT

The Link-Belt Company has elected Ralph M. Hoffman to the position of vice-president, delegating to him the general direction and supervision of sales for the company. Mr. Hoffman, a mechanical engineer from the University of Minnesota, came with the Link-Belt organization in 1923 as manager of the Link-Belt Muse & Gottfried Co.'s Seattle branch. From 1931 to 1939 he served as vice-president and sales manager of this subsidiary, with headquarters at San Francisco. In 1940 he was appointed assistant to the president at the home office, 307 N. Michigan Ave., Chicago, where he will continue his headquarters in his new position.

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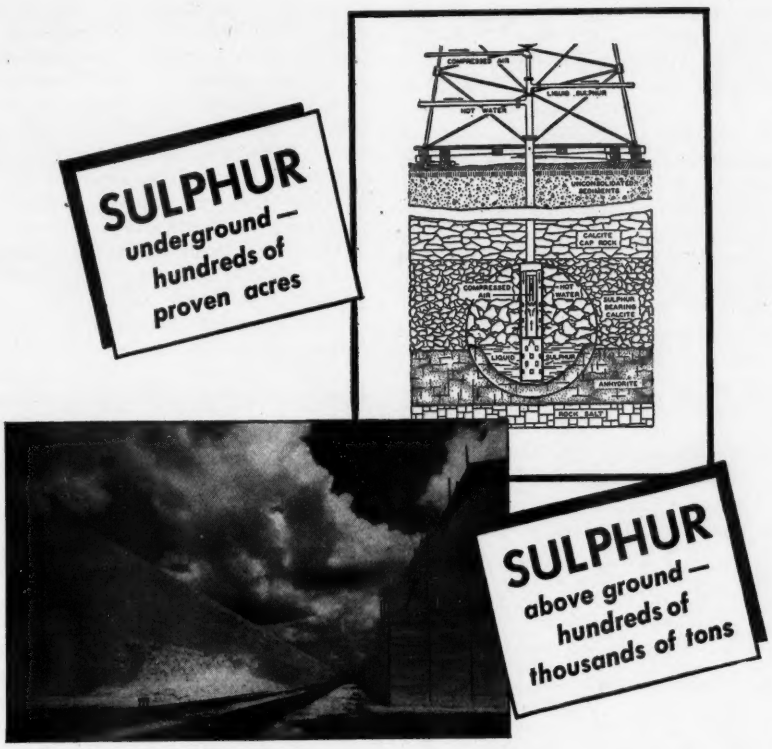

Twenty-Two Years of Preparedness

On March 19, 1919, Texas Gulf Sulphur Company first produced Sulphur.

The growth and development of Texas Gulf Sulphur Company coincides with the peace time growth and development of the chemical industry in the United States. It was started in response to the urgent demands of the times and has grown through the years of uncertainty which followed.

As in 1917, Sulphur plays a large part in the plans for National Defense, but today the United States is assured of ample supplies. Texas Gulf's Sulphur stocks of nearly three million tons, ample producing facilities and reserves should eliminate any threat of shortage during the present emergency.

TEXAS GULF SULPHUR CO.
75 E. 45th Street New York City
Mines: Newgulf and Long Point, Texas

POTASH IN 1940

(Continued from page 9)

An important production of potash salts is from the saline deposits at Trona, California, by the American Potash & Chemical Corporation, where they are obtained as co-product with borax, sodium carbonates, sodium sulfate, lithium compounds, and bromine. There is also a production of potash from saline deposits at Wendover, Utah, by Bonneville, Ltd. Other potash salts are produced in connection with cement plant dust by the North American Cement Corporation at Security, Maryland, and from distillery waste by the United States Industrial Chemicals, Inc., Baltimore, Maryland.

Imports of potash increased 18.5 per cent to 289,037 tons of fertilizer and chemical salts containing about 118,690 tons of K_2O. Although this represents an increase over 1939, it is less than ⅓ of the quantity imported in 1937. Only a few thousand tons were received from Germany, Belgium, and the Netherlands, but cargoes from France continued to arrive until about the middle of June.

JUSTUS LIEBIG, THE MAN

(Continued from page 11)

"Manufacturies of manure will be established, in which the farmer can obtain the most efficacious manure for all varieties of soils and plants. Then no artificial manure will be sold whose exact amount of efficacious elements is not known; and this amount will be the scale for determining its value."

The influence of Liebig and his school upon agriculture was so overwhelming chemical that for the next half century after the publication of his book chemistry was assumed to be the whole of agriculture. Agricultural chemistry became so much a household word that almost exclusive stress was placed upon it and the world heard little about agricultural physics, agricultural biology, agricultural meteorology, and other sciences that enter into the operations of husbandry. The sole importance of chemistry was so ingrained in the public mind that Liebig's pupil Charles M. Wetherill was the first scientist to be appointed in the U. S. Department of Agriculture in 1862. For many years after the establishment of agricultural experiment stations, in the creation of which Liebig's graduates played so important a part, it was tacitly assumed by State authorities that chemists were the only ones qualified to be the directors of these institutions.

The chemical inspection of commercial fertilizers, another idea of Liebig and the chief occupation of early experiment stations, had much to do with this attitude. Now that this regulatory activity has been largely transferred to State departments, horticulturalists, agronomists and other agricultural scientists have displaced chemists to a considerable extent from the role of the directorship of agricultural research. This has not meant, however, any diminution in the effects of Liebig's teachings on present day agriculture, for his chemical outlook has so permeated agronomy, horticulture, plant and animal physiology, forestry and other agricultural sciences that his influence is still felt in nearly every branch of husbandry. This is shown by the large number of distinctly chemical papers which are presented at the meetings of different agricultural scientific societies.

There is not space in this paper to speak in detail of Liebig's vast influence in different branches of pure and applied chemistry, in plant and animal physiology, in medicine, in pharmacy, in hygiene, in nutrition and in other branches of science. His outlook was intensely practical and his ultimate aim was improving the conditions of his fellow men.

The infusion of a new spirit in the study of science was perhaps Liebig's greatest ac-

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Information and references available on request.

AMERICAN POTASH & CHEMICAL CORPORATION
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Pioneer Producers of Muriate of Potash in America

See Page 4

complishment. Adolf Mayer, one of the few surviving students of Liebig and a most acute critic of agricultural chemistry, once remarked:

"Even though the sharp tests of criticism should succeed in reducing to nothing all of the tangible accomplishments of Liebig in agricultural chemistry, the moral significance of his influence can never be denied."

Few great chemists have possessed to the same degree as Liebig the double endowment of discovery and exposition. The vigor of his statements, the aptness of his examples, the humor of his anecdotes, and the brilliance of his imagination, both in his lectures and in his books, were most effective in helping to secure a wide acceptance of the principles which he announced. His erroneous conclusions upon many questions and the bitter polemical spirit of some of his writings should not detract from the splendor of his achievements. More than any other investigator he indicated the directions in which the future science of agricultural chemistry was to proceed.

LIEBIG AND THE ORGANIC NUTRITION OF PLANTS

(Continued from page 7)

high as 60 per cent in some cases, in the amount of fertilizer used. At the same time a marked improvement in yield and quality of crop was obtained.

The roots of the plant are dependent upon the top for their organic food supply. In order that the roots may function properly in absorbing and conducting moisture and mineral nutrients to the top, the top must synthesize sufficient food and conduct it to the roots. High-carbohydrate low-protein corn seeds produce seedlings with larger root-to-top ratios than low-carbohydrate high-protein seeds when grown with nutrient solution free from or low in nitrogen. If nitrogen is added to the nutrient solution, the root-to-shoot ratio is decreased markedly. Analyses show that this is due to the fact that, in the presence of the added nitrogen, the carbohydrate reserves are used with the nitrogen in synthesizing compounds which are used in increasing top growth. In the absence of sufficient carbohydrate reserves, root growth is retarded. Similar explanations may account for the variable results obtained in the application of small amounts of nitrogenous fertilizers in the hill of corn. Many experiments have shown that in some cases increases, in other cases no increases, and in still other cases actual decreases in yield are obtained. If root development is retarded sufficiently by the application of the nitrogen, it may decrease moisture and mineral nutrient absorption sufficiently late in the season to result in a decrease in yield.

Fall applications of nitrogenous fertilizers to winter wheat in some instances have been found to increase, in other cases to decrease, and in other cases to have no effect on the percentage of protein in wheat. Applications of nitrogen during the early periods of growth tend to increase the degree of vegetative development of the plant. The increased size of the plant offers increased opportunity for the synthesis of carbohydrates and may result in a larger number of heads due to increased tillering. Both of these factors may result in conditions favoring a larger yield of wheat without an increase in the percentage of protein or at times even in a decrease in percentage of protein. If sufficient nitrogen is applied so that more is present than is used in the extra vegetative extension, it is possible for the early applications to increase the protein content of the grain. On the other hand applications of nitrogen at periods close to the heading time increase the amount of available nitrogenous nutrients in relation to the available carbohydrates and result in wheat of higher protein content.

The absorption and utilization of nitrogenous salts by the plant is markedly influenced by the available supply of carbohydrates or the opportunity for their synthesis in the plant. Thus temperature, light and moisture supply are important factors involved. Ammonium salts or nitrates may be quite toxic to plants when applied to the soil if the carbohydrate content of the plant is low. The same concentration of nitrogenous salts may cause no injury when the plants have a good supply of carbohydrates or an opportunity to synthesize them freely.

The effect of sunshine, temperature, moisture and the treatment given the above-ground

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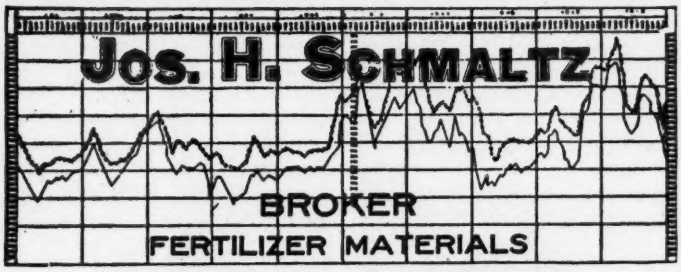

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portions of the plant, such as pruning, clipping or pasturing, affect the ability to synthesize carbohydrates and other organic nutrients. Thus they play a very important role in determining the responses obtained from fertilizer applications and other soil treatments. They may be the deciding factor in determining whether favorable or unfavorable practical results are obtained. Frequently these important relations of organic nutrients are ignored by students of fertilizers and soils.

Effect of Vitamins and Hormones

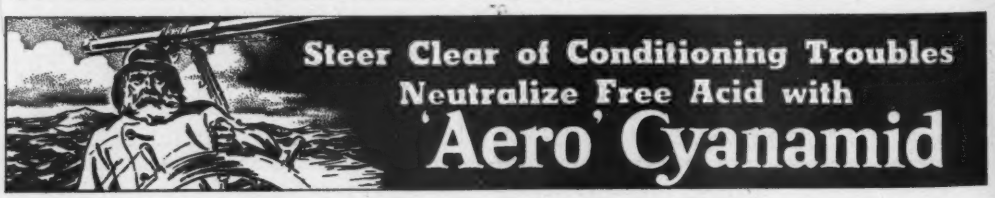
Recently much attention has been given to the role that plant hormones and vitamins play in the growth and development of plants. The auxins of which three are known, auxin a, auxin b, and hetero-auxin, play an important part in the growth of plants. The auxins appear to exercise an important function in determining the direction of growth under the influence of light and gravity, in the initiation of roots and the growth of buds. Practical application has been made of indol-acetic acid and other synthetic chemicals in the stimulation of roots on cuttings. Treatment of cuttings with these substances in many cases results in the development of more roots. In some cases cuttings which are difficult to root without treatment may be rooted after treatment.

A small amount of vitamin B_1 seems to be required by plants. Tissue culture experiments have demonstrated that it is necessary for the growth of roots of flowering plants. But most higher plants, as for instance wheat, corn, tomatoes, peas, beans, etc., appear to synthesize sufficient vitamin B_1 for their needs in the leaves from which the roots obtain their supply. These plants fail to show responses to application of vitamin B_1. A few plants, of which Camellia is an example, have been found to produce only very limited amounts of vitamin B_1 in their leaves. This plant, when grown in sand culture, responds to application of vitamin B_1.

At least three factors appear to influence the response of plants to application of Vitamin B_1. The first factor is the amount of B_1 synthesized by the plant itself. If this amount is large, as in the case of most of the common farm crops, the roots receive all that they need. Such plants cannot be expected to respond to applications of vitamin B_1. The second factor is the amount of vitamin B_1 contained in the soil. It is probable that soils rich in organic matter contain considerable amounts of vitamin B_1. The third factor is the kind of fertilizer applied. Animal manures, seed meals, leaf molds, fish meal and activated sewage sludge have been shown to contain significant amounts of vitamin B_1.

Unfortunately, attempts have been made recently to exploit the use of synthetic vitamin B_1 for application to the soil, both in its pure form and when added to commercial fertilizers. Unwarranted claims, for which there is no evidence based on carefully controlled experiments under practical conditions, have been made for its effect in promoting plant growth. The following is from a recent statement prepared in the California Institute of Technology: "Vitamin B_1 has been shown to be essential for the growth of roots. Experiments have also shown that, under a few special laboratory conditions, applications of vitamin B_1 may benefit the growth of certain species of plants. There is, however, an almost complete absence of *carefully controlled* field trials of the efficiency of vitamin B_1 under practical conditions, and until the results of such trials become available it is impossible to say where and when vitamin B_1 will fill a useful place in horticultural practices. In conclusion, it may be stressed that it is premature at the present time to definitely recommend vitamin B_1 for plant use on anything but an experimental scale."

Much has been added to our knowledge of the organic nutrition of plants during the one hundred years since Liebig so vigorously attacked the old humus theory and advanced the mineral theory of plant nutrition. A clearer understanding of the role of organic nutrients in plant growth and development has made possible an interpretation of the influence of many cultural practices on plant responses. Many experiments which appeared to yield conflicting results have been clearly interpreted on the basis of this knowledge. Sounder and more profitable practical methods of agriculture have resulted therefrom.



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This list contains representative concerns in the Commercial Fertilizer Industry, Including fertilizer manufacturers, machinery and equipment manufacturers, dealers in and manufacturers of commercial fertilizer materials and supplies, brokers, chemists, etc.
For Alphabetical List of Advertisers, see page 33.

ACID BRICK
Charlotte Chem. Laboratories, Inc., Charlotte, N. C.
Chemical Construction Corp., New York City.

ACID EGGS
Chemical Construction Corp., New York City.

ACIDULATING UNITS
Chemical Construction Corp., New York City.
Sackett & Sons Co., The A. J., Baltimore, Md.

AMMO-PHOS
American Cyanamid Co., New York City.

AMMONIA—Anhydrous
Barrett Company, The, New York City.
DuPont de Nemours & Co., E. I., Wilmington, Del.
Hydrocarbon Products Co., New York City.

AMMONIA LIQUOR
Barrett Company, The, New York City.
DuPont de Nemours & Co., E. I., Wilmington, Del.
Hydrocarbon Products Co., New York City.

AMMONIA OXIDATION UNITS
Chemical Construction Corp., New York City.

AMMONIATING EQUIPMENT
Sackett & Sons Co., The A. J., Baltimore, Md.

AUTOMATIC ELEVATOR TAKEUPS
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.

BABBITT
Sackett & Sons Co., The A. J., Baltimore, Md.

BAGS AND BAGGING—Manufacturers
Bagpak, Inc., New York City.
Bemis Bro. Bag Co., St. Louis, Mo.

BAGS—Cotton
Bemis Bro. Bag Co., St. Louis, Mo.

BAGS—Paper
Bagpak, Inc., New York City.
Bemis Bro. Bag Co., St. Louis, Mo.

BAGS (Waterproof)—Manufacturers
Bemis Bro. Bag Co., St. Louis, Mo.

BAGS—Dealers and Brokers
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Baker & Bro., H. J., New York City.
Huber & Company, New York City.
Jett, Joseph C., Norfolk, Va.
Taylor, Henry L., Wilmington, N. C.
Wellmann, William E., Baltimore, Md.

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Atlanta Utility Works, East Point, Ga.
Bagpak, Inc., New York City.
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BAG-CLOSING MACHINES
Bagpak, Inc., New York City.

BAG PILERS
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Link-Belt Company, Philadelphia, Chicago.

BEARINGS
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.

BELT LACING
Sackett & Sons Co., The A. J., Baltimore, Md.

BELTING—Chain
Atlanta Utility Works, East Point, Ga.
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

BELTING—Leather, Rubber, Canvas
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Sackett & Sons Co., The A. J., Baltimore, Md.

BOILERS—Steam
Atlanta Utility Works, East Point, Ga.

BONE BLACK
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Armour Fertilizer Works, Atlanta, Ga.
Huber & Company, New York City.

BONE PRODUCTS
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Armour Fertilizer Works, Atlanta, Ga.
Ashcraft-Wilkinson Co., Atlanta, Ga.
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Bradley & Baker, New York City.
Huber & Company, New York City.
Jett, Joseph C., Norfolk, Va.
McIver & Son, Alex. M., Charleston, S. C.
Schmaltz, Jos. H., Chicago, Ill.
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BORAX AND BORIC ACID
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Pacific Coast Borax Co., New York City.

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Huber & Company, New York City.
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Keim, Samuel L., Philadelphia, Pa.
McIver & Son, Alex. M., Charleston, S. C.
Schmaltz, Jos. H., Chicago, Ill.
Taylor, Henry L., Wilmington, N. C.
Wellmann, William E., Baltimore, Md.

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BUYERS' GUIDE

For an Alphabetical List of all the Advertisers, see page 33

BUCKETS—For Hoists, Cranes, etc., Clam Shell, Orange Peel, Drag line, Special; Electrically Operated and Multi Power
Hayward Company, The, New York City.
Link-Belt Company, Philadelphia, Chicago.

BURNERS—Sulphur
Chemical Construction Corp., New York City.

BURNERS—Oil
Monarch Mfg. Works, Inc., Philadelphia, Pa.
Sackett & Sons Co., The A. J., Baltimore, Md.

CABLEWAYS
Hayward Company, The, New York City.

CARBONATE OF AMMONIA
American Agricultural Chemical Co., New York City.
DuPont de Nemours & Co., E. I., Wilmington, Del.

CARS—For Moving Materials
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

CARTS—Fertilizer, Standard and Roller Bearing
Atlanta Utility Works, East Point, Ga.
Sackett & Sons Co., The A. J., Baltimore, Md.

CASTINGS—Acid Resisting
Charlotte Chem. Laboratories, Inc., Charlotte, N. C.
Duriron Co., Inc., The, Dayton, Ohio.

CASTINGS—Iron and Steel
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.
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CEMENT—Acid-Proof
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Chemical Construction Corp., New York City.

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Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

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Baker & Bro., H. J., New York City.
Barrett Company, The, New York City.
Bradley & Baker, New York City.
DuPont de Nemours & Co., E. I., Wilmington, Del.

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Wellmann, William E., Baltimore, Md.

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Fairlie, Andrew M., Atlanta, Ga.
Sackett & Sons Co., The A. J., Baltimore, Md.
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Shuey & Company, Inc., Savannah, Ga.
Stillwell & Gladding, New York City.
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Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

CONCENTRATORS—Sulphuric Acid
Chemical Construction Corp., New York City.
Fairlie, Andrew M., Atlanta, Ga.

CONDITIONERS AND FILLERS
American Limestone Co., Knoxville, Tenn.
Phosphate Mining Co., The, New York City.

CONTACT ACID PLANTS
Chemical Construction Corp., New York City.

COPPER SULPHATE
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Wellmann, William E., Baltimore, Md.

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Link-Belt Company, Philadelphia, Chicago.
Link-Belt Speeder Corp., Chicago, Ill., and Cedar Rapids, Iowa.
Sackett & Sons Co., The A. J., Baltimore, Md.

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Taylor, Henry L., Wilmington, N. C.
Wellmann, William E., Baltimore, Md.

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For an Alphabetical List of all the Advertisers, see page 33

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Jeffrey Manufacturing Co., The, Columbus, Ohio.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

DRYERS—Direct Heat
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Sackett & Sons Co., The A. J., Baltimore, Md.

DRIVES—Electric
Link-Belt Company, Philadelphia, Chicago.

DUMP CARS
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

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ELECTRIC MOTORS AND APPLIANCES
Atlanta Utility Works, East Point, Ga.
Sackett & Sons Co., The A. J., Baltimore, Md.

ELEVATORS
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Jeffrey Manufacturing Co., The, Columbus, Ohio.
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

ELEVATORS AND CONVEYORS—Portable
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.

ENGINEERS—Chemical and Industrial
Chemical Construction Corp., New York City.
Fairlie, Andrew M., Atlanta, Ga.
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

ENGINES—Steam
Atlanta Utility Works, East Point, Ga.
Sackett & Sons Co., The A. J., Baltimore, Md.

EXCAVATORS AND DREDGES—Drag Line and Cableway
Hayward Company, The, New York City.
Link-Belt Company, Philadelphia, Chicago.
Link Belt Speeder Corp., Chicago, Ill., and Cedar Rapids, Iowa.

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American Cyanamid Co., New York City.
Armour Fertilizer Works, Atlanta, Ga.
Farmers Fertilizer Co., Columbus, Ohio
International Agricultural Corp., New York City.
Phosphate Mining Co., The, New York City.
U. S. Phosphoric Products Division, Tennessee Corp., Tampa, Fla.

FISH SCRAP AND OIL
Ashcraft-Wilkinson Co., Atlanta, Ga.
Baker & Bro., H. J., New York City.
Bradley & Baker, New York City.
Huber & Company, New York City.
Jett, Joseph C., Norfolk, Va.
McIver & Son, Alex. M., Charleston, S. C.
Taylor, Henry L., Wilmington, N. C.
Wellmann, William E., Baltimore, Md.

FOUNDERS AND MACHINISTS
Atlanta Utility Works, East Point, Ga.
Charlotte Chem. Laboratories, Inc., Charlotte, N. C.
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

GARBAGE TANKAGE
Wellmann, William E., Baltimore, Md.

GEARS—Machine Moulded and Cut
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

GEARS—Silent
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.

GELATINE AND GLUE
American Agricultural Chemical Co., New York City.

GUANO
Baker & Bro., H. J., New York City.

HOISTS—Electric, Floor and Cage Operated, Portable
Hayward Company, The, New York City.
Jeffrey Manufacturing Co., The, Columbus, Ohio.

HOPPERS
Atlanta Utility Works, East Point, Ga.
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Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

IMPORTERS, EXPORTERS
Armour Fertilizer Works, Atlanta, Ga.
Ashcraft-Wilkinson Co., Atlanta, Ga.
Baker & Bro., H. J., New York City.
Bradley & Baker, New York City.
Wellmann, William E., Baltimore, Md.

IRON SULPHATE
Tennessee Corporation, Atlanta, Ga.

INSECTICIDES
American Agricultural Chemical Co., New York City.

LACING—Belt
Sackett & Sons Co., The A. J., Baltimore, Md.

LIMESTONE
American Agricultural Chemical Co., New York City.
American Limestone Co., Knoxville, Tenn.
Ashcraft-Wilkinson Co., Atlanta, Ga.
Baker & Bro., H. J., New York City.
Bradley & Baker, New York City.
Wellmann, William E., Baltimore, Md.

LOADERS—Car and Wagon, for Fertilizers
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.

MACHINERY—Acid Making
Atlanta Utility Works, East Point, Ga.
Charlotte Chem. Laboratories, Inc., Charlotte, N. C.
Chemical Construction Corp., New York City.
Duriron Co., Inc., The, Dayton, Ohio.
Fairlie, Andrew M., Atlanta, Ga.
Monarch Mfg. Works, Inc., Philadelphia, Pa.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

MACHINERY—Coal and Ash Handling
Hayward Company, The, New York City.
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.

MACHINERY—Elevating and Conveying
Atlanta Utility Works, East Point, Ga.
Hayward Company, The, New York City.
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

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MACHINERY—Power Transmission
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MAGNETS
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Stedman's Foundry and Mach. Works, Aurora, Ind.

MANGANESE SULPHATE
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MIXERS
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Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

NITRATE OF SODA
American Agricultural Chemical Co., New York City.
Armour Fertilizer Works, Atlanta, Ga.
Ashcraft-Wilkinson Co., Atlanta, Ga.
Baker & Bro., H. J., New York City.
Barrett Company, The, New York City.
Bradley & Baker, New York City.
Chilean Nitrate Sales Corp., New York City.
Huber & Company, New York City.
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Schmaltz, Jos. H., Chicago, Ill.
Wellmann, William E., Baltimore, Md.

NITRATE OVENS AND APPARATUS
Chemical Construction Corp., New York City.

NITROGENOUS ORGANIC MATERIAL
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Ashcraft-Wilkinson Co., Atlanta, Ga.
Baker & Bro., H. J., New York City.
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Huber & Company, New York City.
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Smith-Rowland Co., Norfolk, Va.
Wellmann, William E., Baltimore, Md.

NOZZLES—Spray
Monarch Mfg. Works, Philadelphia, Pa.

PACKING—For Acid Towers
Charlotte Chem. Laboratories, Inc., Charlotte, N. C.
Chemical Construction Corp., New York City.

PANS AND POTS
Stedman's Foundry and Mach. Works, Aurora, Ind.

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Southern Phosphate Corp., Baltimore, Md.
Taylor, Henry L., Wilmington, Del.
Wellmann, William E., Baltimore, Md.

PIPE—Acid Resisting
Duriron Co., Inc., The, Dayton, Ohio.

PIPES—Chemical Stoneware
Chemical Construction Corp., New York City.

PIPES—Wooden
Stedman's Foundry and Mach. Works, Aurora, Ind.

PLANT CONSTRUCTION—Fertilizer and Acid
Chemical Construction Corp., New York City.
Fairlie, Andrew M., Atlanta, Ga.
Sackett & Sons Co., The A. J., Baltimore, Md.

POTASH SALTS—Dealers and Brokers
American Agricultural Chemical Co., New York City.
Armour Fertilizer Works, Atlanta, Ga.
Ashcraft-Wilkinson Co., Atlanta, Ga.
Baker & Bro., H. J., New York City.
Bradley & Baker, New York City.
Huber & Company, New York City.
International Agricultural Corp., New York City.
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Schmaltz, Jos. H., Chicago, Ill.
Taylor, Henry L., Wilmington, Del.
Wellmann, William E., Baltimore, Md.

POTASH SALTS—Manufacturers and Importers
American Potash and Chem. Corp., New York City.
Potash Co. of America, Baltimore, Md.
United States Potash Co., New York City.

PULLEYS AND HANGERS
Atlanta Utility Works, East Point, Ga.
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

PUMPS—Acid-Resisting
Charlotte Chem. Laboratories, Inc., Charlotte, N. C.
Duriron Co., Inc., The, Dayton, Ohio.
Monarch Mfg. Works, Inc., Philadelphia, Pa.

PYRITES—Brokers
Ashcraft-Wilkinson Co., Atlanta, Ga.
Baker & Bro., New York City.
Jett, Joseph C., Norfolk, Va.
Wellmann, William E., Baltimore, Md.

QUARTZ
Charlotte Chem. Laboratories, Inc., Charlotte, N. C.

RINGS—Sulphuric Acid Tower
Chemical Construction Corp., New York City.

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SEPARATORS—Air
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Link-Belt Company, Philadelphia, Chicago.
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SEPARATORS—Magnetic
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Sackett & Sons Co., The A. J., Baltimore, Md.
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SHOVELS—Power
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Link-Belt Company, Philadelphia, Chicago.
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Sackett & Sons Co., The A. J., Baltimore, Md.

SPRAYS—Acid Chambers
Monarch Mfg. Works, Inc., Philadelphia, Pa.

SPROCKET WHEELS (See Chains and Sprockets)

STACKS
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SULPHATE OF AMMONIA
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Ashcraft-Wilkinson Co., Atlanta, Ga.
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Taylor, Henry L., Wilmington, N. C.

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Taylor, Henry L., Wilmington, N. C.
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Wellmann, William E., Baltimore, Md.

SUPERPHOSPHATE—Concentrated
Armour Fertilizer Works, Atlanta, Ga.
International Agricultural Corp., New York City.
Phosphate Mining Co., The, New York City.
U. S. Phosphoric Products Division, Tennessee Corp., Tampa, Fla.

SYPHONS—For Acid
Monarch Mfg. Works, Inc., Philadelphia, Pa.

TALLOW AND GREASE
American Agricultural Chemical Co., New York City.

TANKAGE
American Agricultural Chemical Co., New York City.
Armour Fertilizer Works, Atlanta, Ga.
Ashcraft-Wilkinson Co., Atlanta, Ga.
Baker & Bro., H. J., New York City.
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Jett, Joseph C., Norfolk, Va.
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Schmaltz, Jos. H., Chicago, Ill.
Smith-Rowland, Norfolk, Va.
Taylor, Henry L., Wilmington, N. C.
Wellmann, William E., Baltimore, Md.

TANKAGE—Garbage
Huber & Company, New York City.

TANKS
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Sackett & Sons, Co., The A. J., Baltimore, Md.

TILE—Acid-Proof
Charlotte Chem. Laboratories, Inc., Charlotte, N. C.

TOWERS—Acid and Absorption
Chemical Construction Corp., New York City.
Fairlie, Andrew M., Atlanta, Ga.

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Hayward Company, The, New York City.
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.

UREA
DuPont de Nemours & Co., E. I., Wilmington, Del.

UREA-AMMONIA LIQUOR
DuPont de Nemours & Co., E. I., Wilmington, Del.

VALVES—Acid-Resisting
Atlanta Utility Works, East Point, Ga.
Charlotte Chem. Laboratories, Inc., Charlotte, N. C.
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Jeffrey Manufacturing Co., The, Columbus, Ohio.
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See Catalog 6-C

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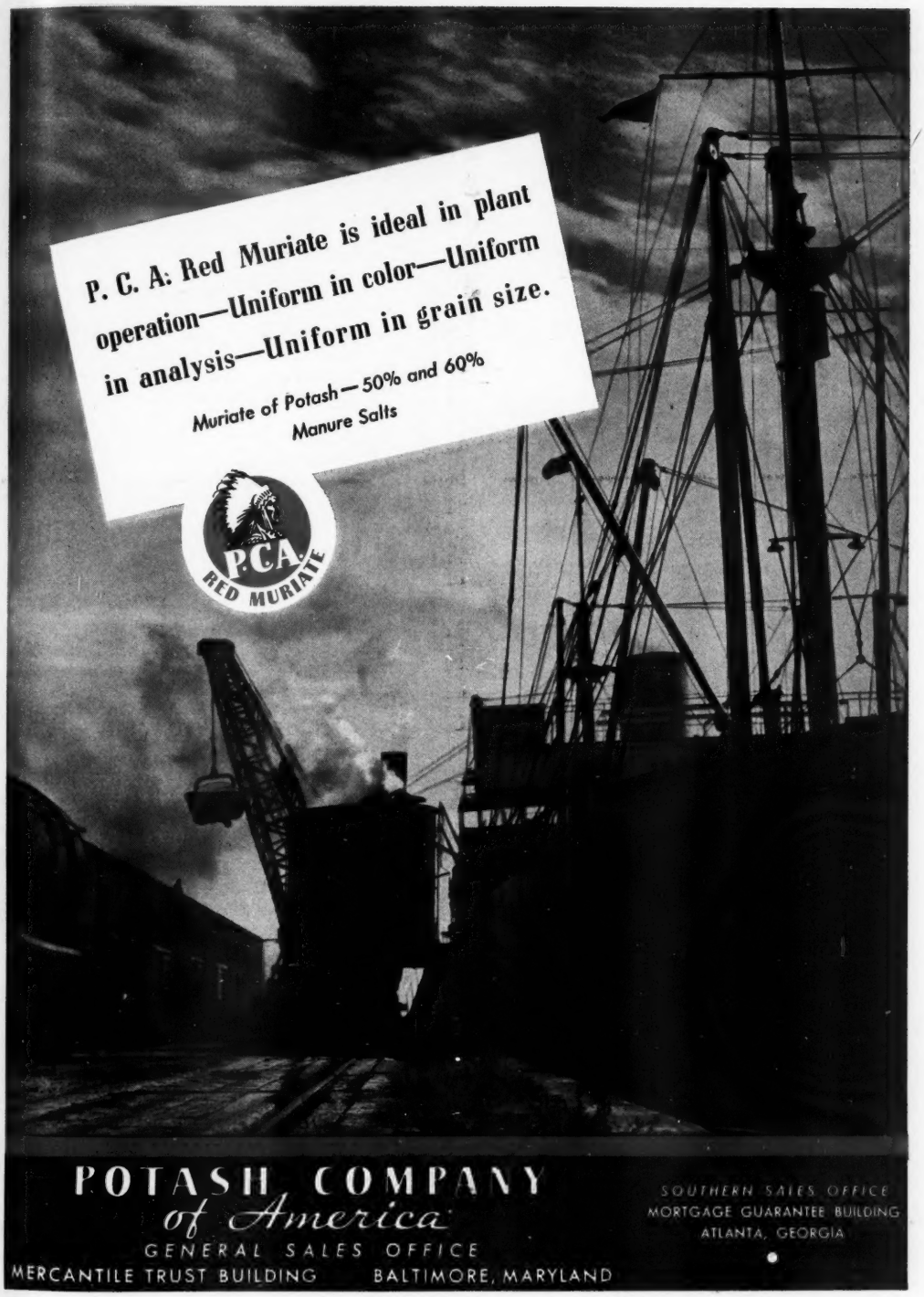

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